McCROMETER

Overcoming Deep Water Challenges For Enhanced Oil Recovery

White Paper

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 Printed in U.S.A. 30122-09 Rev. 1.0/7-15

White Paper

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Overcoming Deep Water Challenges For Enhanced Oil Recovery

Maximizing oil recovery in offshore fields can require a myriad of enhanced oil recovery (EOR) techniques which can add complexity at subsea depths. In 2012, Petrobras was seeking to couple high pressure carbon dioxide (CO_2) injection with other unconventional EOR techniques. While used extensively in onshore fields, offshore CO_2 injection, especially in deep water developments, adds an extra level of complexity that had not previously been employed.

Most CO_2 injection pressures top out at around 1000psi (69bar) so the fluid is in its true gas state. This is no problem for onshore production fields where well pressures are moderate, but operating gas injection pressures in an offshore field may be two to five times higher. At those pressures, CO_2 becomes a supercritical fluid (*see Figure: 1*). A supercritical fluid is defined as behaving like a gas but having the density of a liquid. To make matters more challenging, around the transition boundary where a gas becomes supercritical, small changes in pressure have significant impact on fluid density.

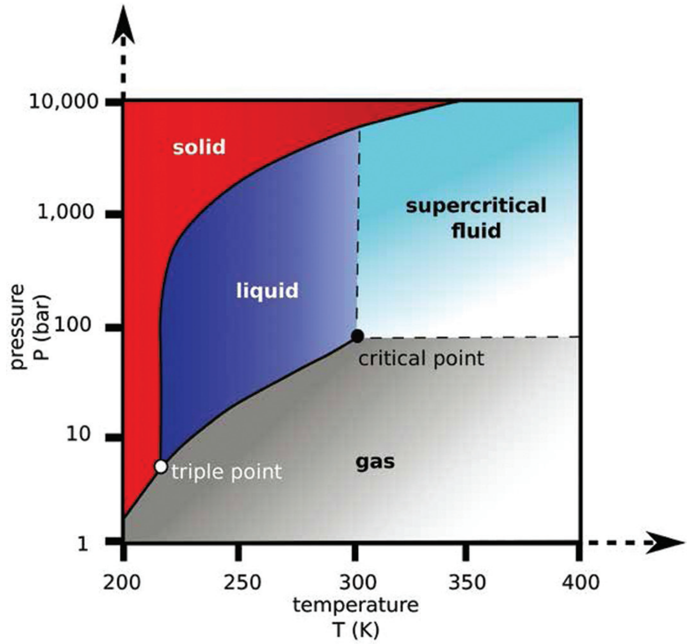

Figure 1: Phase Diagram For CO_2

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One might ask, what makes CO_2 an interesting case? Natural gas systems are operated at the same pressures or higher in the Oil and Gas industry every day. How are the lessons of operating natural gas lines different than operating CO_2 systems? To answer that, let's take a look how pressure changes affect natural gas (NG) and CO_2.

To understand this you need to look at how the density of NG responds to increasing pressure (*see Figure: 2*). There is a clear linear relationship. Then consider what happens to CO_2 in the same conditions. The relationship is far from linear. So the question must be asked, how does one accurately measure a supercritical fluid?

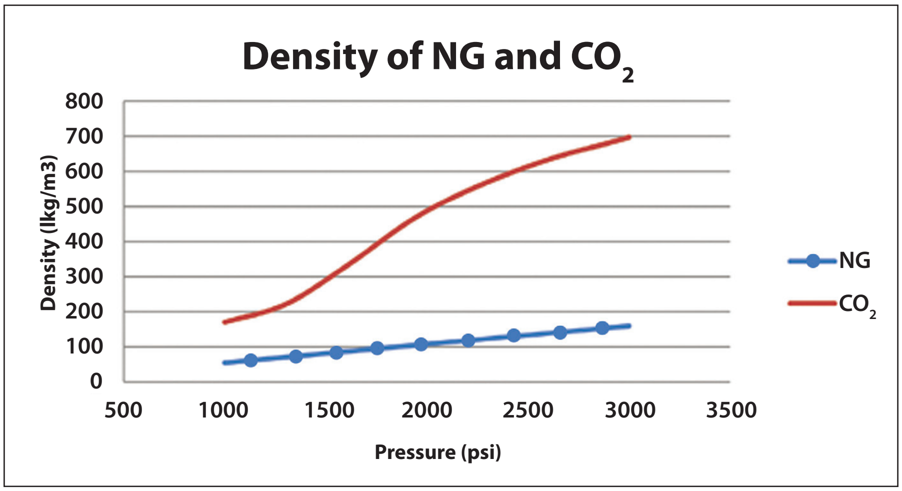

Figure 2: Density Of NG And CO_2

This is the very question Petrobras was asking their engineers in 2012. They approached McCrometer, inquiring about the V-Cone Differential Pressure flow meter as a candidate. The requirements, while few, were daunting. The V-Cone must be accurate to within +/-2.0% while metering CO_2 in a supercritical state at pressures up to 7830psig (54MPa). While the V-Cone flow meter is well-known for the ability to work in demanding environments while minimizing space due to the ability to condition the fluid, this was a new challenge.

To test the performance of the V-Cone in this application, McCrometer contracted National Engineering Labs (NEL) to perform a computer simulation of operating conditions. NEL is a world-class provider of technical consultancy, research, testing, flow measurement and program management services. McCrometer chose to simulate the process rather than test a production V-Cone in a supercritical test stand as no such test stand currently exists that can produce the same flow pressures and temperatures in this CO_2 application.

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First a production V-Cone would be water calibrated by NEL to determine the as built discharge coefficient (Cd). NEL would then duplicate the water test in their computational fluid dynamics (CFD) computer to ensure the model was accurate, followed by simulating the supercritical CO_2 system. To test a range of operation, a combination of two temperatures and two pressures would be used at each of the three test flow rates.

The CFD analysis predicted the actual Cd to better than three per cent compared to the water calibration. While not perfect, the report shows the computer modelling physics are accurate enough to test the suitability of the V-Cone in supercritical service.

The work then shifted to simulating supercritical CO_2, and the results were positive. The simulated supercritical flow Cd is very close to both the simulated water Cd and as calibrated water Cd. One can then conclude that a production V-Cone calibrated in water would have an error not exceeding two percent in actual service.

The benefits of utilizing CO_2 injection in ever widening applications are many. CO_2 acts as a natural solvent and helps strip the oil from rock making it more efficient than just water flooding. It also dissolves into the hydrocarbon (HC) liquids, lowering viscosities and making them lighter and easier to recover. Instead of re-injecting produced HC Gas to accomplish similar goals, the gas can instead be sold, increasing well profitability.

Injecting carbon dioxide doesn't have the same environmental stigmas attached that gas and water injection techniques have often weathered. In fact, CO_2 injection has far reaching environmental benefits unlike conventional EOR techniques.

Taking the exhaust gas off of a power plant or manufacturing facility not only provides an inexpensive and abundant source for CO_2, it also prevents tons of the greenhouse gas from being released into the atmosphere. Injecting gas not only enhances oil recovery efforts, it also acts as greenhouse gas storage. The operator of a field in Canada reports they inject 5000 tons of CO_2 per day. That is the same as burning 530,000 gallons (2.2M liters) of gasoline per day or the equivalent of removing 200,000 cars from the road.

Utilizing the V-Cone in supercritical systems gives the user the benefits of accurate measurement in any installation or fluid condition. The revolutionary V-Cone is already known for reducing metering footprint, it is now also a part of the solution to reduce the industries carbon footprint.

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